The Geology and Physiography of Parts of the Darling Range near Perth, by **E. de C. Clarke,** M.A., Lecturer in Geology, University of Western Australia, and **F. A. Williams,** B.Sc.

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Contents.

I.—INTRODUCTION.

The quarries of Boya, Stathams, Mahogany Creek and Parkerville in the Darling Range near Perth produced, in 1924, material valued at £68,973*, but apparently no geological map or systematic description of the surroundings of these sources of wealth has ever been produced, although many short papers on physiography or on details of geologic interest have appeared in scientific journals and government publications. This paper, a first move towards supplying this deficiency, might be described as "Notes to accompany geological and topographical maps of two typical areas in the Darling Range." It is a summary of the field-work done by many students at various times during the period 1921-1926. The field-work, which formed part of the course in geology in the University of Western Australia, was done partly by individuals working singly, partly by groups. It would be invidious to attempt naming all who took an active part in the work and we must content ourselves with mentioning those who have made independent maps and reports on certain sections, namely: W. Cohen, K. Finucane, F. Forman, I. Harms, A. Hill, J. Hosking, and E. Owen. The compilation of the map of the Darlington Area from data obtained from the Lands and Surveys and Land Titles Departments was done by Miss E. Lamborne, B.Sc., and Miss F. Armstrong. We are much indebted to Messrs. N. Bartlett and C. Hogarth of the above-named departments and to Mr. J. Parr of the Water Supply Sewerage and Drainage Department for placing at our disposal all available survey data regarding the areas with which we were concerned. One of us (F.A.W.) did all the field and laboratory work of Roleystone Area, mapped about one quarter of Darlington Area and is largely responsible for the petrological section of the paper.

As is well known, the higher levels of the Darling Range are almost everywhere laterite-covered, and information regarding the foundation rocks must be sought mainly in the valleys of streams which have cut below the laterite level. The Darlington

* Information kindly supplied by the Government Statistician.

Area, which occupies about 6 square miles in a broad portion of the Helena Valley 10 miles east of Perth and includes, or is near, the most important quarries, is the obvious place in which to begin any examination of Darling Range geology. Next to the Helena, the Canning and Swan Valleys seem likely to offer most information of the kind required. One and a half square miles of the Canning Valley, the Roleystone Area, 18 miles S.E. of Perth, have therefore been examined, and a beginning has been made on an area in the Swan Valley.

Both the Roleystone and Darlington Areas receive on the average about 36 inches of rain per annum, and in their natural state were covered with forest consisting mainly of Jarrah (*Eucalyptus marginata*) and Marri (*E. calophylla*). Much of the Roleystone area has been cleared and cultivated (fig. 1). The Darlington Area (Plate XXI) has lost most of its large trees by fire and felling, but only a small portion is cultivated.

FIG. 1.—The valley of Slab Gully Creek, a typical view in the Roleystone Area.

Both areas have been subdivided by accurate surveys made for the purpose of sale, etc., into blocks of a few acres. These blocks were plotted on our working plans and were used as a basis for geological and topographical mapping which was done either by pacing, by chaining, or by tacheometry. The form-lines were determined mainly by aneroid, corrected either by comparison with a barograph kept in camp or by frequent checking on known heights on pipe-lines or railways.

Although much of the matter set out below was collected by other workers we must be held responsible for everything which is not definitely attributed to some other observer. In the reports submitted by the various students are many interesting observations not reproduced here, partly because in this paper we try to emphasize only the outstanding geologic and topographic features. We hope that, a beginning having been made, further detail will soon follow from others.

II.—PHYSIOGRAPHY.

A. General.

The two areas under consideration lie in the valleys of the Helena and Canning Rivers, two of the westerly-flowing streams which according to Jutson (1914 p. 128) were consequent on the formation of the Darling Fault, and which, having steeper courses, were able to capture and dismember the senile north-south drainage. An account of the physiography therefore is mainly a description of the watercourses. It may be noted here that the only perennially flowing streams are the Canning River and Piesse Brook, though it is merely the presence of Mundaring Weir which makes the Helena dry during the summer months. Smith's Mill Brook usually carries water until December, all the other watercourses become dry in early summer, except in a few places where fed by springs which issue from the junction of epidiorite dykes and granite.

The Roleystone Area, being smaller and confined to one side of the valley, does not furnish any detail of special value, though features of interest in the Darlington Area occur in it also, in a less obvious manner. The remarkable bend of the Canning in the Roleystone Area is probably due to the capture of an old north-south stream, though clear evidence such as one gets higher up the Canning is lacking, because more extensive erosion has removed much of the evidence of the courses and levels of the older streams.

A reconnaissance for fourteen miles up the valley of the Canning shows that the main valley is mature for about two miles east of the Darling fault line scarp, above that, to the end of the traverse, the hills gradually close in and become steeper and the river is broken by cascades and rapids. There are also several right-angled bends in the valley, the north-south arms of which are probably portions of the older dismembered drainage system. The tributaries, which generally have a more or less north-south direction, flow for the greater part of their course through shallow wide valleys, but their lower parts flow through narrow deep valleys. What length of a tributary is thus rejuvenated seems to depend on the volume of water carried. Essentially young tributaries showing no sign of having been carved out of pre-existing valleys are rare. Obviously these features accord with Jutson's history of the Darling Range rivers.

No similar reconnaissance of the Helena has been made, but from scattered observations we believe that for a distance of about 12 miles above the Darlington Area the same features would be found. From detailed work at Gorrie's Farm, about 6 miles south of Chidlow and 16 miles by river above Darlington Area, we know that, in its upper reaches, the Helena valley is mature.

B. Physiography of the Darlington Area.

In contrast to the Roleystone Area the Darlington Area includes the full width of the Helena Valley for three miles and has several features of interest.

1. *Helena River.*—The river enters the Area flowing in a W.S.W. direction through a steep-sided valley with occasional broken water, but at its junction with Piesse Brook, which enters from the south, it turns to the N.W. and passes for more than a mile through a gorge-like valley, its grade still that of an immature stream. Shortly after emerging from the gorge it is joined from the N.E. by Smith's Mill Brook, and from here to the western edge of the Area has the characters of a mature stream. Half a mile beyond Smith's Mill Brook junction it turns sharply to the W.S.W. again.

2. *Tributaries.*—Three types of tributary are distinguishable:

(a) Wholly immature tributaries—All but six of the many watercourses which enter the Helena in the Darlington Area are of this type. They rise within the limits of the valley itself and are insequent, owing their existence simply to the deepening and widening of the main valley. Their courses are pretty evenly steep throughout, and waterfalls are rare; but owing to the shortness of their season of activity, they are unable to degrade as fast as the main stream, and several steepen visibly as they near the Helena River.

(b) Rejuvenated tributaries—Smith's Mill and Cohen Brooks and a stream which enters the Helena opposite the mouth of Smith's

Mill Brook flow in their upper parts through wide shallow valleys in the laterite-covered Darling Peneplain, but on reaching the slopes of the Helena Valley they have the same character as the wholly immature tributaries. The mature part of Smith's Mill Brook lies outside the Area. Piesse Brook is a much larger perennial stream, whose grade is only a little steeper than that of the Helena; in other words it has excavated a valley nearly as pronounced as that of the Helena. Its upper portion however, six miles south of the Darlington Area, has the same mature character as the other streams of this group.

(c) Beheaded tributaries—Greenmount and Hosking Brooks have little in common except their beheaded character. Greenmount Brook now has short immature insequent south-flowing head waters followed by a mile of meandering mature course running more or less parallel to the Helena. West of the Area it again becomes steep and immature. At the transition between head and middle waters is a broad flat wind gap, in which, in a deep railway cutting, is disclosed partially consolidated sandy alluvium. About a mile farther from Perth the railway, which is here following up Smith's Mill Brook, passes through a more extensive deposit of the same nature. It is probable, both from the unnaturally mature character of the middle-waters of Greenmount Brook, and from the occurrences of alluvium in general alignment with the upper part of Smith's Mill Brook, that the middle part of Greenmount Brook is a lower portion of Smith's Mill Brook, beheaded by a more actively corrading insequent tributary of the Helena. Hosking Brook is a short watercourse, mature except at its source at an abrupt saddle, from the other side of which a short immature watercourse drains into Piesse Brook. The course of Hosking Brook is straight, and in alignment with the mature portion of the Helena below Smith's Mill Brook, with which also its contours harmonize so well that anyone looking up the valley from below Boya would suppose it to be the main river valley, and would not suspect the existence of the narrow gorge to the left. Mr. J. S. Hosking, who mapped this portion of the Area, attributes this apparent case of river capture to the abnormal activity of Piesse Brook following on the uplift along the Darling Fault; this activity he ascribes mainly to Piesse Brook being situated in a zone of more easily corraded rock. This explanation must be tested by investigation of the country east and south of the Darlington Area and its publication should be an incentive to further work.

3. *Influence of geological structures on stream-direction.*—(a) Jointing and shearing—In some parts, particularly along the

gorge of the Helena, the courses of small streams are parallel to the major joints or to the occasional shear zones.

(b) Relative resistance of granite and epidiorite—The fact that in so many places prominent spurs have a core of epidiorite confirms Aurousseau's observation that epidiorite is as a rule more resistant to corrasion than granite. There is however considerable variation in the resistance to weathering shown by various epidiorites. So far it has not been possible to ascribe this to variation in structure or composition.

4. *High level terraces of Helena Valley.*—The form-lines on the map (Plate XXIII), and also the photograph of the topographic model (Plate XXII) show that the steep slopes of the valley are in places interrupted by flattened areas, and that these fall into two series, one lying at about 450 feet, the other at about 250 feet above sea level. These are probably the remnants of two successive periods of long continued lateral corrasion, when the river had practically attained base level. In other words, they record two long pauses in uplift along the Darling Fault. Indistinct signs of similar terracing may be seen in the Canning Valley, and along the Darling fault scarp.

III—GEOLOGY.

A. General.

The areas under discussion are essentially composed of granitic rocks; almost entirely massive in the Darlington, predominantly gneissic in the Roleystone Area. The granites and gneisses are traversed by a great number of epidiorite dykes varying in width from a fraction of an inch to a chain or more, and traceable in some instances for more than a mile along their strike. Whether all these dykes are practically coeval is not certain. Shear zones traverse the granite and some of the epidiorite dykes, and along some of the shear zones there has been widespread replacement by silica.

B. Acid Rocks.

1. *Granite.*—The granite is a coarse-grained biotite variety, generally with porphyritic microcline. In the Roleystone Area it is more or less gneissic; in the Darlington Area no truly gneissic granite has been found.

Mineralogically the rocks from the two areas are identical. The microcline phenocrysts average about half an inch in length in the gneissic, and about [illegible] inch in the massive variety. Carlsbad twins are abundant. The crystal shape is well developed, but the edges often exhibit a peculiar nibbled outline, as if the crystal had undergone partial resorption. The cross-hatching is clearly defined, the lamellae being spindle-shaped. The inclusions comprise subidiomorphic to allotriomorphic crystals of oligoclase largely altered to scaly white mica and kaolin, rounded blebs of quartz and partly chloritised biotite. The turbidity of the oligoclase is in marked contrast to the comparatively fresh condition of the microcline.

The ground-mass is of coarse but variable grainsize and of the usual granitoid texture. Patches of a micropegmatitic intergrowth of quartz and plagioclase feldspar are not uncommon. The oligoclase is largely altered to small flakes of colorless mica and kaolin. The microcline of the ground-mass is of a later generation than the phenocrysts, and like the latter, is comparatively fresh. Biotite occurs as rather ragged crystals and aggregates, in part chloritised. Many of the biotite crystals contain inclusions, probably of zircon, surrounded by pleochroic haloes. The quartz does not call for comment.

The strongly gneissic varieties consist of alternate bands or lenses of biotite-rich and feldspar-rich rock. The longest axec of the microcline phenocrysts, and the cleavage planes of the biotite are parallel to the direction of the gneissic banding.

The development of both the porphyritic texture and the gneissic banding is extremely variable—one or both may be absent. Generally the more strongly gneissic varieties are the more conspicuously porphyritic. The trend of the banding in the Roleystone Area is approximately north and south.

Field-work has shown that the varieties merge gradually into one another; no definite boundaries can be drawn between them. Nor does microscopic examination of the entire range of gneissic and porphyritic varieties show any persistent differences by which the granites could be divided into two or more types. It seems therefore that the granites are a petrological unit showing wide variations from place to place in the development of porphyritic and gneissic textures.

2. *Fine-grained biotitic segregations.*—Small exposures of these are fairly common in the Roleystone Area. They are dark green, fine grained and megascopically of thoroughly basic appearance. Under the microscope they are seen to consist of a fine even-grained aggregate of biotite and quartz with microcline and plagioclase.

Most exposures show these segregations to be lenses parallel to the gneissic banding, less commonly they occur as subangular blocks strung out parallel to the gneissic banding. They are cut by both biotite pegmatite and quartz veins.

Segregations identical with those of the Roleystone Area are exposed in Statham's Quarry just west of the S.W. corner of the Darlington Area, but have not been noted in the Darlington Area.

3. *Acid and ultra-acid intrusions.*—These occur as veins, dykes and irregular masses in the granite, into which they merge gradually. The types represented are:—

(a) Aplitic biotite granite;
(b) Aplite;
(c) Biotite pegmatite;
(d) Muscovite pegmatite;
(e) Quartz veins.

None except the aplitic biotite granite shows any approach to gneissic structure.

Field-relations and microscopic features indicate that they should be placed in the above order in respect of age, the aplitic granite being the oldest. The position of the muscovite pegmatite is, however, uncertain.

(a) The aplitic granite occurs in irregular masses as much as two chains wide. It is a medium even-grained rock composed of microcline and oligoclase, with quartz and biotite.

(b) The exposures of aplite are generally smaller than those of the aplitic granite. The rock occurs in dykes and veins, and is in many places associated with pegmatites. Petrologically it differs from the aplitic granite in the very small development of biotite.

(c) Numerous veins of biotite pegmatite, up to a foot or so in width, cut the gneissic banding of the granite without being distorted by it. They also cut the aplite and aplitic granite. The chief mineral constituent is microcline in crystals up to six inches across. Oligoclase is subordinate to microcline. As in the granite the microcline is the less turbid of the two feldspars. Biotite occurs in "books" up to six inches across. The quartz is partly interstitial and partly intergrown with feldspar. Also quartz veinlets, not optically continuous, traverse cracks in the microcline crystals.

(d) Exposures of muscovite pegmatite are rare, except within a small area east of the creek shown on the western side of the Roleystone map. The minerals are microcline, oligoclase, quartz and muscovite.

(e) Quartz veins are found cutting all the above intrusives. They constitute the extreme acid member of the series.

All these rocks appear to represent the residual acid portions of the granitic magma, and to have been intruded before the complete consolidation and cooling of the main mass of granite.

A number of quartz veins associated with regions of shearing and fracture in the granite, and presenting well defined contacts with the latter are considered, for reasons to be given in the section "quartz reefs in shear-zones," to be later than the quartz veins just mentioned.

4. *Magmatic History.*—The features noted above may be tentatively ascribed to the following series of events:—

Magma of granitic composition welled up into the zone of crystallisation. The earliest minerals to form were biotite, plagioclase and quartz. The centres of crystallisation of the biotite, plagioclase, and quartz crystals appear to have been closely spaced, giving rise to a large number of small crystals. Microcline began to crystallise at more widely separated points, and grew to comparatively large crystals, which often included a number of small oligoclase, quartz and biotite individuals. This microcline is represented by the phenocrysts in the rock now exposed. The process continued until the crystallisation of portions of the magma was approaching completion.

Renewal of the activity of intratelluric forces then caused the further movement of this partly crystallised magma, and its injection into the position the granite now occupies. During this movement mixing of magma fractions in various stages of crystallisation took place. Those portions in the more advanced stages of crystallisation developed a gneissic structure, but those portions in which but little crystallisation had taken place could not retain the impress of the renewed movement, and solidified as massive rocks. The progressive stages of crystallisation are represented by the gradations from gneissic and porphyritic to even-grained massive granites as exposed to-day. Under these conditions no definite boundaries would exist between the different types of granite. The more rapid cooling of the magma in the second magma chamber—its present position—was responsible for the smaller size of the second generation of crystals which form the matrix of the porphyritic granites.

The residual ultra-acid liquors from the crystallising magma were then forced into the solidified, or partly solidified, granite to form the series of acid and ultra-acid intrusions, the texture of which is more or less continuous with the surrounding country.

Some of the aplitic granite was involved in the movements and received a gneissic structure. The other acid and ultra-acid intrusions were injected after the flowing of the granite ceased.

The fine grained biotitic segregations may perhaps represent portions of a derived magma, resulting from the gravitational segregation of the earliest formed minerals produced in the first stage of crystallisation of the magma.

C. Basic Rocks.

1. *General field-occurrence and petrology.*—The granite is invaded by a network of basic dykes referable to the epidiorite group.

The accompanying maps show that the size and disposition of these dykes in the Darlington and Roleystone areas, are similar.

FIG. 2.—Epidiorite dyke in contact with granite in Greenmount Brook near western edge of Darlington Area. White-barked eucalypts on the dyke visible in background.

Their mode of field-occurrence is mentioned in the physiography section. There is little difficulty in mapping them fairly accurately in the steeper parts of the areas; they can in many places be seen outcropping for many chains, and in the intervals their courses are indicated by the abundance of epidiorite boulders, by the dark red soil, and by the predominance of a white barked eucalypt which contrasts strongly with the dark trunks of the Marri and Jarrah which predominate on granite. However, on some of the high-level terraces, boulders of granite and epidiorite are promiscuously distributed, probably by the river corrading laterally during pauses in the uplift along the Darling Fault. On these areas, though much time was spent in trying to decipher the courses of the dykes, the mapping may be inaccurate.

Petrologically, average specimens of epidiorites from the two areas are identical, and there appears to be little variety except in coarseness of grain. Hand-specimens are of a uniform dark green colour, the feldspars only showing clearly in weathered specimens. In a few specimens small grains of pyrite are visible. The grain size varies with the width of the dyke. The margins are in every instance fine grained and more or less sheared, differing markedly in this respect from the acid and ultra-acid intrusions. Veins of epidote are common, both in the epidiorite itself and in the enclosing granite. It may be noted that irregular quartz veins of small size are not uncommon in the epidiorites.

In thin section the rock is seen to consist of lath shaped crystals of plagioclase, set in a ground-mass of uralite. Much of the plagioclase is zoned; in average composition it is a labradorite. The uralite forms a fibrous mat between the feldspars. It is partly chloritised. There are traces of ophitic structure, plates of uralite enclosing the plagioclase crystals.

The three analyses A, B, and C below of epidiorites from the Darlington Area were made by Mr. F. F. Allsop as part of his course in Geology in 1924.

The analyses D, E, and F of epidiorites from the Darling Range near the areas under discussion have been made available to us through the kindness of Dr. E. S. Simpson, Government Analyst and Mineralogist, in whose laboratory they were made.

	A	B	C	D	E	F
SiO_2	50.67	49.28	49.04	50.96	49.53	49.22
Al_2O_3	14.01	13.62	16.55	11.89	12.92	12.62
Fe_2O_3	1.38	3.13	2.52	2.54	2.60	3.16
FeO	5.20	11.92	9.84	13.64	11.40	11.09
MnO	not determined			.34	.35	.33
MgO	8.12	8.29	7.43	6.26	6.24	6.42
CaO	13.16	7.35	9.70	9.94	10.37	10.59
Na_2O	2.04	2.68	2.54	2.68	2.08	1.86
K_2O	2.32	.29	.28	.29	.36	.30
H_2O-	.23	.18	.18	.16	.09	.12
H_2O+	.70	.70	.61	.05	2.21	2.24
TiO_2				1.84	2.13	2.00
BaO					nil	nil
ZrO_2					nil	nil
CO_2				nil	nil	nil
P_2O_5	.12	.28	.25	nil	.16	.09
FeS_2				trace	.28	.22
Cr_2O_3, V_2O_3, Cu_2S					trace	trace
Total	97.95	97.72	98.94	100.59	100.72	100.26

A—Darlington Area, 40 chains south of mouth of Smith's Mill Brook.

B & C—Boya Quarries.

D—Smith's Mill, 2 miles east of Darlington. Dr. Simpson notes that the rock is composed almost entirely of labradorite and hornblende.

E & F—Quarry at Bickley Brook Reservoir, near Roleystone Area. E is from the fine grained edge. F from the coarse central part of the dyke. Dr. Simpson finds that the minerals in order of abundance are: Hornblende, plagioclase, ilmenite, magnetite, quartz, leucoxene, apatite, epidote.

2. *Relation to other rocks.*—The basic dykes cut the acid and ultra-acid intrusions, and must have been injected at some period subsequent to the consolidation of the granite and its associated acid intrusions. The shear zones and related later quartz reefs are clearly seen to cut epidiorite dykes in several places. There are, however, three places (right bank of Helena 20 chains below mouth of Piesse Brook, ridge on left bank 50 chains below mouth of Piesse Brook, small creek which flows past east side of Boya Quarries) in which dykes were, with hesitation, mapped as passing unaffected through the shear zones. In each case the ground was obscured.

3. *Inter-relationships of the basic rocks.*—The weight of evidence favours the view that there is not more than one age of epidiorite in the areas described. It is true that instances have been seen of one dyke faulting and displacing another, that the surface of contact between granite and some dykes is a "head" along which the two rocks separate readily, while in others the two rocks are so closely adherent that they break more readily across than along the junction surface, and that there are a few dykes which possibly cross the shear planes which truncate other dykes; but unless more conclusive evidence of marked differences of age amongst the dykes is found it is best, in view of their petrological identity, to regard them as all of substantially the same age. In the country just east of Piesse Brook Mr. K. Finucane has found a number of instances of epidiorite invaded by small dykes and veinlets of epidiorite, and also of more acid rock. Further work in this neighbourhood will quite likely cause at least modification of our tentative conclusion as to the single age of the epidiorites.

D. Quartz reefs in shear-zones.

The occurrence of belts of shearing in the Darling Range has long been known, but the relation between these zones and certain quartzose rocks outcropping along the Darling Fault Scarp has not apparently been recognised.

The shear zones of the Darlington Area are of two types:

(1) Shear-zones without secondary quartz,

(2) Shear-zones with partial replacement of sheared rock by quartz.

1. A fine outcrop of the first type can be seen from the road 15 chains S.E. of Darlington railway station. The rock here is a sericite schist derived from the granite.

2. A good exposure of the second type occurs on the western edge of the Area 85 chains south of the Helena River, where a belt of sheared granite, associated with a quartz reef, can be traced along the strike for about 600 yards.

Detailed study of this outcrop in the field, and the examination of thin sections, indicate that the secondary quartz was formed in part by the metasomatic replacement of the original sheared granite.

The central zone, about 4 feet wide, consists of massive fine-grained sugary quartz containing scattered grains of clear quartz of larger size than the ground-mass. Under the microscope the ground-mass is seen to be a fine-grained aggregate of quartz showing no undulose extinction. The scattered fragments of clear quartz exhibit pronounced undulose extinction, and are similar in size, shape, and strain structure to the quartz grains in the unreplaced sericite schist. The largest quartz grains appear to have been original constituents of a schist the other minerals of which are now almost entirely replaced by secondary quartz.

The central quartz reef merges on either side into quartz rock with a well defined cleavage parallel to the schistosity of the whole belt, and containing lenses of much weathered sericite schist, some only a fraction of an inch wide, also parallel to the schistosity. Proceeding farther towards the edge of the belt, the amount of secondary quartz is seen to become less and less, the rock passing into a normal sericite schist. A network of quartz veins cuts both the replaced and unreplaced rock.

There are many similar quartz reefs in the district, several of which are clearly continuous across epidiorite dykes, but few of the exposures are good. The sheared granite generally weathers more rapidly than the more massive enclosing country, but the presence of the reefs is indicated by the abundance of quartz floaters, often associated with fragments of schistose rock. The larger pegmatite veins give rise to somewhat similar quartz blows, but the presence of fragments of kaolinised feldspar indicates that the underlying rock is pegmatite, whereas, if pieces of schistose rock are found, the underlying rock is a quartz reef.

After investigating the quartz reefs of the Darlington Area, a visit was made to part of the Darling Fault Scarp east of Gosnells, where there is a very conspicuous outcrop of quartz rock. This formation was found to be, in its essential features, identical with the Darlington Area type, but developed on a much larger scale. The belt of shearing varies in width from a few chains up to about a quarter of a mile and trends approximately north and south, i.e., parallel to the Darling Fault. The quartz reefs are several chains wide, but vary in width along the strike. Like the Darlington Area type, they are composed of massive sugary quartz in the middle, and grade through schistose quartz into sheared granite on either side. The whole belt is traversed by numerous quartz veins, disposed both parallel to and across the planes of schistosity. Several basic dykes were observed to end abruptly at the edge of the shear zone.

The unsheared granite of this locality is massive. The massive granite is continuous as far south as the Roleystone Area. Farther south, at Arundale, similar quartz reefs have been noted in gneissic granite about a hundred yards east of Coombs' Quarry.

The formation of these belts of shearing and silicification is of later date than the intrusion of basic dykes, across which, with the possible exceptions noted under "basic rocks," shearing persists. The basic dykes themselves are intrusive into the granite and its associated acid and ultra-acid derivatives. It seems most probable therefore that these quartz reefs were formed later on, and are quite distinct from, the quartz veins previously referred to as representing ultra-acid residual liquors from the granite magma squeezed into the consolidating granite.

E. Later Rocks.

1. *Laterite.*—Only in a few places do the Darlington and Roleystone Areas rise to the "Laterite Level" which in this region lies between 600 and 700 feet above sea level. The laterite of the Darling Ranges has been described and discussed elsewhere (Simpson 1912, Woolnough 1918, Clarke 1919) and we have nothing of interest to add.

2. *Alluvium.*—Two types of alluvium occur in the Darlington Area, that forming the flats in the lower part of the Helena, and high level alluvium in the former course of Smith's Mill Brook. The first does not call for comment, the second is described in the Physiography section.

3. *Talus banks.*—The tributaries of the Helena generally flow in narrow V-shaped valleys. In many of these, running parallel to the watercourse, and at heights varying from three to fifty feet above it, is a steep sided bank 1 to 3 feet high of angular rock fragments, the steep side facing the stream. Similar features were noted in the Roleystone Area. The origin of these banks is puzzling. They look at first sight as if of human origin—made in clearing a track—but the places in which they occur make that theory untenable. Possibly Jutson's explanation (1921)—differential erosion—of the parallel lines of rock debris on Lake Goongarrie which of course occur under very different climatic and topographic conditions is applicable to these banks. In the Darling Ranges the unequal erosion is due to the varying resistance to weathering of granite and epidiorite, at Lake Goongarrie wind-erosion of soft shales unprotected by quartz rubble is the agent.

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Explanation of Plates.

XXI—Looking west down Helena Valley from spur on left bank of Cohen Brook. Shows characteristic topography and vegetation.

XXII—Photograph of a model of the Darlington Area of which horizontal scale is 10 chains to 1 inch, vertical 200 feet to 1 inch.

XXIII—Geological map of the Darlington Area.

XXIV—Geological map of the Roleystone Area.

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